CHEMICAL INDUSTRIES IN ANCIENT INDIA (FROM THE MAURYAN ERA TO THE GUPTA AGE)

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In tracing the history of science and and technology in ancient India we are "confronted by a jigsaw of transmissions which render our interpretation of these discoveries all the more difficult and uncertain."[1] A number of small chemical industries became manifest since the Mauryan rule. The growth was completely based on the trade system, improved communications and developed technology. The quality of chemical variety, of materials manufactured and utilised by the people determined the cultural pattern as well as changes in economic trends. Due to a gradual sustained growth of economic activities even in the post-Mauryan times (185 B.C. - 467 A.D.), agriculture, trade, mining, minerals and industry became prominent.[2]

The use of metals and their production has been one of India's most ancient of sciences.[3] It was closely linked to developments in metallurgy and chemistry. The *Arthasastra of Kautilya* describes that a considerable progress was made in the arena of metal industry. The mining of iron, copper, tin, lead, etc. and their uses in this regard were notable. This revolutionised the material culture of the period under review. The *Arthasastra* describes in detail about the extraction of gold, silver, copper, lead, tin and iron from their ores[4] and the process of smelting gold-ores.[5] It also appears that furnaces for smelting and forging of objects were known. It lays down that the produce of various mines should be turned into articles of use in the respective workshops or factories (*Karmantas*).[6] It further mentions factories to be started for the manufacture of articles of bitumen,[7] copper, lead, tin, brass, steel, bronze, iron, trade in metal-wire, etc.[8]

In post-*Mauryan* days when urban elements reached their peak, especially, under the *Sakas-Kusanas* and the *Satavahanas*, arts and crafts industries witnessed a remarkable growth. The *Buddhist* scripture *Digha Nikaya* mentions about two dozen trades and 36 kinds of workers.[9] *Mahavastu* gives a list of trades of workers living in the town of *Rajagriha*,[10] the *Milindapanha* enumerates 75 occupations of which 36 are related to various types of crafts.[11] Of these, eight crafts were connected with working of mineral products,

e.g. gold, silver, lead, tin, copper, brass, iron and precious stones. A variety of brass, zinc, antimony and red arsenic are also mentioned.[12] Even the *Samhitas* of *Charaka* (c.1st-2nd century A.D.) and *Sushruta* (c.4th century A.D.)[13] provide several references to the uses of minerals and metals in medicine.

Rasaratnakara of *Nagarjuna*, who was a contemporary of *Kanishka*,[14] and a famous *Buddhist* monk and alchemist, presents in his work the preparations of mercury (*rasa*) compounds. It also gives a survey of the status of metallurgy and alchemy besides extraction and purification of metals such as silver, gold, tin and copper. To prepare the 'elixir of life' and other substances from mercury, *Nagarjuna* refers to the use of animal and vegetable products, apart from minerals and alkalis.[15] To dissolve diamonds, metals and pearls, he suggests the use of vegetable acids — gruel and juices of fruits and plants. He also mentions the process of distillation, liquefaction, sublimation and roasting.[16] He also wrote *Uttaratantra* as a supplement to *Susruta-Samhita* dealing with the prepartion of medicinal drugs. Some other medical chemists also did succeed in producing many important alkalis, acids and metallic salts by the simple process of calcination and distillation.[17] All these facts are a brilliant testimony to an advanced and specialized working of metal productions.

A case study of *Mathura* may be relevant here. By 300 A.D. it grew as the centre of many technologies - cotton-weaving (*Sataka*), silk-weaving, sandstone, glass, metalsmith industries particularly iron, steel and brass, goldsmith, etc.[18]

The cultural enrichment, flourishing trade and economic prosperity led to replenishing the royal treasury of the Guptas. This promoted technology. The fourth to fifth century A.D. saw the compilation of the encyclopaedic works on materials, metals, minerals, gems, textiles and other industries products. The treatises such as *Angavijja*, a *Jain* scripture in *Prakrit* by *Pubbayariya*,[19] *Namalingamusasanama* or *Amarakosa*, a lexicon in *Sanskrit* by *Amarasimha*, *Brahatsamhita* of Varahmihira, the various *Ratnasastra* texts, etc. were complied during this period, bearing witness to the prolific diversification of crafts and minerals, metals and trade. Craftsmen mentioned in the *Amarakosa* are "... plasterer (mason), weaver, tailor, painter, sharpener of weapons (armourer), cobbler and leather-worker, blacksmith, goldsmith ... bangle-maker (from chank shells), coppersmith...."[20] The *Brhatsamhita* contains some useful references which display advanced metallurgical skill. It maintains how gold was tested, melted, heated in the fire and

hammered for testing its purity. We even find the mention of silver mines (*Rajatakara*), red-hot copper to cast it into different shapes, lead and bronze used in the preparations of metal-joining cement (*Vajrasamaghata*) in the recipes of hardening of steel (*Shastrapana*).[21] In fact, during the Gupta period agriculture, metal working, minting of coins, weaving, mining, silk and cotton industries, dyeing, smithy, manufacturing of oil, cosmetics and perfumes etc. were the main occupations and industries.[22]

Here it is interesting to note that Greks and Romans have also given accounts which shed light on the metal industry in ancient India. Megasthanes points out, "... it (India) has ... numerous underground views of all sorts of metals, ... gold and silver, and copper and iron ... tin and other metals, which are employed in making articles for use and ornaments, ... implements and accoutrements of war".[23] Quintus Curtius[24] and Philostratus[25] also refer to the use of silver and gold. To add, Pliny (*Natural History*), Ptolemy (*Geography*) and the anonymous author of the *Periplus of the Ertyrean Sea* corroborate that mining and metal production were standard practices in the commercial life of the ancient Indians.[26] An Arab scholar Al-Idrisi wrote in Al-hadid *Al-Hindi* (of 12th century A.D.) that "the Hindus excel in the manufacture of iron, ... They also have workshops wherein are forged the most famous sabres in the world... It is impossible to find anything to surpass the edge that you get from Indian steel."[27] This reference is clearly related to the organised industry in contemporary India. It also shows that the technique of smelting and casting iron was well developed.

Besides, in the inscriptions of the period, weavers, goldsmiths, workers in metal, smiths, perfumers, etc. figure as donors of caves, tablets, pillars of Buddhist monuments which suggest that their crafts were in a flourishing state.[28]

We also get archaeological evidences about the technique of mining-operation through which chemical industries were established. This is obvious as gold was brought from Hatti mines (belonging to pre-Asokan days), Mangalur gold mine of Gulbarg and Kolar gold field in Karnataka. The other gold mines were at North Ananthpur, Andhra Pradesh and the Dharwar reef mines in Maharashtra.[29] At Maski an ancient gold metallurgical plant was discovered nearby a cave containing Asokan inscripiton. It appears that Phoenician traders carried away the gold.[30] Gold was used as ornaments, coins and decorative pieces. The archaeological sites at Rajghat, Taxila, Vaishali, Uraiyur in Tiruchairapalli, Hulas Khero in Lucknow have yielded a number of gold objects.[31] Here, it is

interesting to note that the Allchins hold that Greek Darhams and Roman Dinars made from Indian gold were in circulation for trade and often smelted for reuse.[32]

The evidence for silver metallurgy could be traced from Sirkap, Vaishali, Rupar etc.[33] It was processed in Rajasthan and Baluchistan, also from the argentiferrous lead ores. It has also been reported to be produced at Ananthpur Gold Field in Andhra Pradesh. The production of silver from argentiferrous galena seems to have been done by.[34]

(i) Smelting of galena, and

(ii) Recovery of silver from crude lead.

It was used in making ornaments, coins, utensils, decorative pieces and other house-hold articles. From the remains found at Rajpura-Dariba, Rampura-Agucha, Zawar etc. of Rajasthan and Ingaldhal of Karnataka it appears that lead, zinc and silver productions took place as far back as c.500 B.C.[35] The Hindustan Zinc Limited informs us through its leaflets and other publications about mining and smelting of zinc done at the aforesaid sites. There is unique evidence for the extensive and semi-industrial production of metallic zinc at the Zawar Area of Rajasthan India achieved the distinction of being the only country in the ancient and the medieval world to produce pure zinc metal (somewhere between 600 to 200 B.C.) and high zinc-brass alloys. This fact has been established only recently by a team of scholars from India and England.[36]

Lead was obtained from its ores-galena. In later period it was used for manufcturing sanitary pipes, moulding dyes, etc. Its compounds also have been used for glazing potteries and in the manufacture of glass Jeyaraj has mentioned the use of cast lead coins in South India in the 2nd to 3rd century A.D.[37]

Excavations at Taxila, Vaishali, Prakash, Rajghat, Kumrahar etc. attest to the fact that the mining of copper was well developed.[38] We also come across the copper-smelting practices at Ambaji,Kumbaria in Gujarat; Bagore, Khetri Copper Workings (done since c.300 B.C.) in Rajasthan; Masabani, Rakhna, Ramachandra Pahara etc. in Singhbhum copper belt (since c.600 B.C.) in Bihar, portions of which the Indian Copper Corporation Limited has so successfully developed. The renowned scholar D.D. Kosambi is true when he states that copper mining developed extensively to the south-east of Bihar.[39] And it is interesting to learn that the nearest copper mines to the Mauryan empire were those of Barangunda and Singhbhum. It has also been suggested that copper and gold mines at Dalbhum in

Chotanagpur were worked from the time of Chandragupta Maurya.[40] Between *c.*200 B.C. & 150 A.D. there was abundance of copper in India and they were exported to West Asian countries through the port of Barygaza (presently Broach in Gujarat).[41] Copper was used for tools, domestic utensils, ornaments coins, decorative pieces, mirror, etc. Thus heaps of slags in those mines show the existence of copper extracting industries in ancient India. The coppersmith of the period used to employ various techniques, viz. hammering, forging and casting for manufacturing of copper objects.[42]

The production of tin has been reported from Hazaribagh, Ranchi and Gaya. The Sanskrit words 'Kastira' (tin) and 'arakuta' (brass) were derived from the Greek 'cassiteros' and 'oreichalkos' respectively.[43] It was used to prepare alloys and coins in ancient India.

From the ore-artifact correlation study we come to know about the process of iron-making during the period. Iron objects have been obtained from various sites like Rajghat, Taxila, Vaishali, Prakash, Kausambi, Sisupalgarh etc. which show the presence of well developed iron technology.[44] Among the iron objects of diverse use, recovered from many archaeological sites, mention may be made of sickles, spades, spoons, knives, razors, spear-heads, swords, axle of spinning wheels, etc. The large scale production of iron had a boom from 200 A.D. to 600 A.D. High quality pure wrought iron blooms were produced in huge quantity and technology was developed in manipulating massive iron structures and welding them. In those days, iron thus processed was mostly wrought iron. It was much esteemed for its purity and hardness. Several iron crucibles and furnaces as well as varied and numerous iron tools and implements also exhibit the existence of a high developed iron industry. Indian iron & steel are mentioned in the *Periplus* as imports into the Abyssinian ports.[45]

The *Iron Pillar of Delhi* (of 23'8" and 6 tonnes) is a classical example of massive production of high class iron.[46] The use of 6 tons of iron for non-utilitarian purpose is a clear proof of a thriving iron industry requiring huge furnaces and workshops. This Iron Pillar has withstood the influence of rain and air till date, meaning thereby that the standard of corrosion chemistry and concept of chemical behaviour of air, water, etc. on the metal was very high. The Indian workers had the full idea of heating and quenching to produce magnetic oxide on the surface. The iron scraps of the Pillar on chemical analysis reveals that the percentage of Iron is 99.720, that of Carbon, Sulphur, Silicon, Phosphorus, Manganese respectively are 0.080, 0.006, 0.046, 0.114 and Manganese is nil. The absence of Mangnese and less quantity of Sulphur and high quantity of

Phosphorus were the unique features of this Iron Pillar.[47] Basham rightly observes that the size and weight of this Iron Pillar could not have been produced by the best European iron founders about hundred years ago.[48]

Steel production also became a highly developed art in this age. The world's first high-carbon steel, an alloy of iron, was a product of ancient India, known as wootz, meaning steel. Wootz is an anglicised version of '*Ukku*' in the languages of the states of Karnataka & Andhra Pradesh. Chemical and metallographic examination of iron objects from Prakash, Koshambi, Besanagar, Taxila, etc. also prove that the technique of converting wrought iron into steel was discovered.[49] Literary accounts suggest that steel from the southern part of the Indian subcontinent was exported to Europe, China, the Arab world and the Middle East.[50]

Furthermore, chemical analysis of ancient Indian coins tell us that the main constituents of coins were gold, silver and copper. The methods of extracting the coinage metals and of minting coins were known to Indians.[51]

Besides, craftsmen of the period were well acquainted with copper and tin alloying called bronze. Similarly the earlier occurrence of zinc in man-made artifacts in the form of the copper alloy known as brass. Moreover, brass was becoming popular for casting images in the Gupta period. Prior to the advent of the Guptas the evidence of brass is limited.[52] A remarkable use of brass was made in the construction work of an unfinished *Vihara* made near Nalanda. The Taxila remains consist of ornaments, toilet articles, surgical and other instruments of this metal and its alloy. A white alloy nickel and copper was in use for coinage and jewellery, and solders made of tin and its alloy have also been discovered.[53]

Besides metal industry, there are references to the making of wines (*Sura*) through fermentation in the *Arthasastra* such as *Medaka*, *Prasanna*, *Asava*, *Aristas*, *Maireya* and *Madhu*.[54] Some of these varieties of wines and there preparations were known in later days also.

Leather work[55] was also done. It was manufactured and purified through different chemical processes. It was of different shapes and sizes. Similarly, making and weaving of clothes was known. The *Arthasastra* elaborately describes about the manufctures of cotton, woolen and silk clothing.[56] Indian spinners and weavers could produce the semi-transparent silks and muslins of extreme thinness. These were much in demand in the Roman empire. In fact, next to

agriculture manufacturing techniques of textile and its industry assumed much importance in the life of the ancient Indians.[57]

Dye industry also existed in contemporary India. Dye was generally herbal and it was used for dyeing clothes.[58] Varahamihira also alludes to the experts in machinery and the professional experts in the composition of dyes and cosmetics. The *Brhatsamhita* has a chapter on Perfumery where Varahmihira gives various recipes for artificial imitation of natural flower scents. There were three great discoveries in the field of chemical technology which enabled Indians during the Gupta period to secure pre-eminence among the nations of the world in manufactures and exports:[59]

(i) the preparation of fast dyes for textile fabrics by the treatment of natural dyes like *Manjishtha* with alum and other chemical;

(ii) the extraction of the indigotin from the indigo plant by a process which is an anticipation of modern chemical methods; and

(iii) the tempering of steel in a manner worthy of advanced metallurgy.

Several empirical recipes related to chemical technology have also been mentioned by Varahmihira in his Brhatsamhita, such as preparation of cement from rocks, metals, etc. known as Vajra-lepa.[60] It is significant that carbon ink was in use during the Kusana period. Sana Ullah has examined the contents of ink pot of Taxila and it was found to contain black carbon mixed with earth.[61]

Pliny holds that glasses were manufactured in ancient India by the rock crystal pieces. Beads, bangles, finger-rings, pully shaped objects were introduced by the craftsmen of the period. Glass slags at several sites like *Rajghat, Taxila, Bhitari, Nalanda*, etc. provide a clear indication of their being factory sites using various moulding and fabrication techniques. The Gupta period is credited with the introduction of utilitarian vessels for the first time in ancient India.[62]

A form of gunpowder has also been discovered. The Sukranitisara refers to various chemical processes to manufacture this gunpowder.[63] However, the date of the text is debatable.

Thus, the development of chemical industries asserts its close linkage with the progress and enrichment of trade and crafts in ancient India. Recent explorations and studies have shown that metal industry was firmly established as a prosperous one. Some of the glory of the material culture during the Mauryas, Kusanas, Satavahanas and the Guptas was due to the Graeco-Roman contacts which not only promoted trade and crafts but also enlightened the Indians through the inflow of novel and at times scientific ideas. The Persians, Greeks and Romans were the first patrons of Indian iron, steel and brass.

The ancient ruins of this age are still a witness to the growth and development of chemical technologies and its utilization for their daily necessities.

NOTES AND REFERENCES

1. P.S. Rowson, *Early Art and Architecture*, A.L. Basham (ed.) *A Cultural History of India*, (New Delhi, 1975), p.208.
2. In fact, the change in economy was strenghtened by the widespread use of iron, extensive cultivation of rice, sugar and cotton, rise and growth of numerous towns, the diversification of crafts coupled with the brisk inland and foreign trade.
3. See my article on Mining in Ancient India (from the Mauryan Era to the Gupta Age), read in the 63rd session of the Indian History Congress, Amritsar session, 2002.
4. R.P. Kangle (ed.), The Kautilya Arthasastra, Bombay University, 1969, Part I, 2.12.2. 2.12.5-6, 2.12.12-15.
5. Ibid., 1.18.8.
6. Ibid., 2.12.18, 2.12.27.
7. Ibid., 2.12.4.
8. Ibid., 2.12.23.
9. H.C. Bhardwaj *Aspects of Ancient Indian Technology*, Delhi, 1979, p.22.
10. A.K. Tyagi, *Science and Technology in Ancient India: A Review in Ancient India*, Publications Division, New Delhi, 1995, p.169.
11. H.C. Bhardwaj, op.cit., p.22.
12. Ibid.
13. A.L. Basham, *The Wonder that was India* Delhi, 1971, p.500. The Indian National Science Academy, New Delhi, has published a volume each on *Caraka Samhita* and *Susruta Samhita* by Priyadaranjan Ray et al., the well-known texts on medicine and surgery respectively.
14. Ibid., p.280.
15. Dilip M. Salwi, *Our Scientist*, New Delhi, 1987, p.23. For a detailed study regarding the science of alchemy see S. Mahdihassan, *Indian Alchemy or Rasayana*, Delhi, 2002.
16. Ibid.
17. A.L. Basham, op.cit., p.500. For an exhaustive study see P. Ray (ed.) *History of Chemistry in Ancient and Medieval India*, Calcutta, 1956.
18. R.S. Sharma, *Perspectives in Social and Economic History of Early India*, Delhi, 1983, pp.170-183.
19. A.K. Biswas and S. Biswas, *Minerals and Metals in Ancient India*, New Delhi, 1996, Vol.II, p.137.
20. B.D. Chattopadhyaya (ed.), *Combined Methods in Indology and Other Writings of D.D. Kosambi*, New Delhi, 2002, p.287. Also see D.D. Kosambi, The Working Class in the Amarakosa, *The Journal of Oriental Research*, Vol.XXIV, Madras, 1954-55, pp.57-59.
21. M.R. Bhatta (ed. and tr.), *Brhatsamhita of Varahmihira*, Delhi, 1987, 6.13. 16.26. 26.9, 43.12, 47.46, 50, 23-26, 57.2-7.
22. S. Saran and R.N. Singh, *History of Science and Technology during Gupta Period*, New Delhi, 1994, p.6.

23. J.W. Mc Crindle (tr.), *Ancient India as Described by Megasthenes and Arrian*, Calcutta, 1877, p.30.
24. J.W. Mc. Crindle (tr.), *The Invasion of India by Alexander the Great*, London, 1896, pp.188-89.
25. J.W. Mc. Crindle (tr.), *Ancient India as Described in Classical Literature*, London, 1901, p.75.
26. G.W.B. Huntington (ed.), *The Periplus of the Erythrean Sea*, London, 1980, p.71. Also see Romila Thapar, *The Penguin History of Early India*, New Delhi, 2003, pp.241, 242, 252.
27. Quoted by A.K. Biswas, *Minerals and Metals in Ancient India*, Vol.I, New Delhi, 1996, p.389.
28. Bhardwaj, op.cit., p.22.
29. F.R. Allchin, Upon the Antiquity and Methods of Gold Mining in Ancient India, *JESHO*, 1962, 5(2), pp.195-211.
30. R.D. Singh, Mining, A.K. Bag (ed.), *History of Technology in India*, New Delhi, 1997, Vol.I, p.56.
31. H.C. Bhardwaj, op.cit., pp.127-30, Also see B.P. Sinha and S.R. Roy *Excavations at Vaishali*, Patna, 1969, p.195. Also see *IAR*, 1965-66, p.51, *IAR*, 1980-81, p.71.
32. R. and B. Allchin, *The Birth of Indian Civilisation* 1968, pp.205, 281-85. Also see F.R. Allchin, op.cit., pp.195-211.
33. S. Saran and R.N. Singh, op.cit., p.203.
34. Ibid., pp.160-61.
35. L. Willies, *Ancient Zinc -Lead-Silver Mining in Rajasthan*, India, 1987, Interim Report, 10(2), pp.81-128.
36. K.T.M. Hegde, P.T. Craddock and V.H. Sonavane, Zinc, Distillation in Ancient India, *Proceedings of the 24th International Archaeometry Symposium*, Washington D.C., 1986, pp.249-58. Also see A.K. Biswas, The Primacy of India in Ancient Brass and Zinc Metallurgy, Indian Journal of History of Science, New Delhi, 1993, 28(4), pp.309-30, Also see A.K. Biswas and S. Biswas, op.cit., Vol.I, pp.351-84.
37. V. Jeyaraj, Study of Andipatti Lead Coins and their Preservations, G. Kuppunam and K. Kumudamni (ed.), History of Science and Technology of India, Delhi, 1990, Vol..VIII, p.99.
38. *Ancient India*, 1964, No.20 and 21. Also see A.S. Altekar and V. Mishra, Report on Kumrahar Excavation, (1951-55), Patna, 1959, pp.130-36. Also see Krishnadeva and V. Mishra, Vaishali Excavations 1950, Vaishali, 1961, pp.58-65.
39. D.D. Kosambi, The Culture and Civilization of Ancient India, London, 1965, p.140.
40. H.C. Bhardwaj, op.cit., pp.22, 98.
41. R.D. Singh, op.cit., p.51.
42. S. Saran and R.N. Singh, op.cit., p.199.
43. A.K. Biswas, Social Factors in the Development of Technology, A.K. Bag (ed.), op.cit., p.696.
44. S. Saran and R.N. Singh, op.cit., pp.112-17, 122. Also see H.C. Bhardwaj, op.cit., p.144.
45. A.K. Tyagi, op.cit., p.169.
46. M.K. Ghosh, The Delhi Iron Pillar and its Iron, *N.M.L. Technical Journal*, 1963, Vol.V, No.1, pp.31-45.

47. Satya Prakash, *Prachin Bharat Mein Rasayana Ka Vikas* (in Hindi), Uttar Pradesh, 1960, pp.784-85. Also see T.R. Anantharaman, *The Rustless Wonder*, New Delhi, 1997.
48. A.L. Basham, op.cit., p.222.
49. V.T. Athavale, Chemical Analysis and Metallographic Examination of Metal Objects, Prakash, 1955 in *Ancient India*, New Delhi, 1967, Nos.20-21, 1964-65, pp.131-39.
50. A.K. Biswas, op.cit., Vol.I, pp.385-93.
51. M.K.B. Sana Ullah, *Annual Reports, A.S.I.* 1921-22, p.125; 1922-23, p.158; 1924-25, p.139.
52. Bhanu Prakash, Metals and Metallurgy, A.K. Bag (ed.), op.cit., pp.148-52. Also see A.K. Biswas, op.cit., Vol.I, pp.351-84.
53. R.D. Singh, op.cit., pp.49-50.
54. *The Kautilya Arthasastra*, Vol.I, 2.25.16.
55. B.D. Chattopadhyaya (ed.), op.cit., p.287.
56. *The Kautilya Arthasastra*, 2.23.1-2.23.19.
57. Kiran Singh, Textiles in Ancient India, Varanasi, 1994, pp.53-76, 118-133.
58. B.N. Seal, The Positive Sciences of the Ancient Hindus, Calcutta, 1915, pp.63-64.
59. Ibid.
60. Ibid.
61. Satya Prakash, op.cit., pp.823-28.
62. S. Saran and R.N. Singh, op.cit., pp.175-204.
63. Satya Prakash, op.cit., pp.788-94, 802-22.